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AAIA

Air Accident Investigation Authority

Fuel Related

(FUEL)

Investigation Report

Accident to Cessna 152, B-HHN

Sam Pui Chau, New Territories,

Hong Kong

26 February 2017

07-2022

AAIA Investigations

Pursuant to Annex 13 to the Convention on International Civil Aviation and the Hong Kong Civil Aviation (Investigation of Accidents) Regulations (Cap. 448B), the sole objective of the investigation and the Investigation Report is the prevention of accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

The then Chief Inspector of Accidents-cum-Director-General of Civil Aviation ordered an inspector’s investigation into the accident in accordance with the provisions in Cap. 448B. As the powers of accident investigation were transferred to the Air Accident Investigation Authority (AAIA) with effect from 10 September 2018, the investigation of the accident was carried on by AAIA.

This accident investigation report contains information of an occurrence involving a Cessna 152 aircraft, registration B-HHN, operated by the Hong Kong Aviation Club (HKAC), which occurred on 26 February 2017.

The National Transportation Safety Board of the United States of America (NTSB), being the investigation authority representing the State of Design and the State of Manufacture, the Civil Aviation Department (CAD), and the aircraft operator, provided assistance to the investigation.

Unless otherwise indicated, recommendations in this report are addressed to the regulatory authorities of the State or Administration having responsibility for the matters with which the recommendation is concerned. It is for those authorities to decide what action is taken.

This Investigation Report supersedes all previous Preliminary Report and Interim Statements concerning this accident investigation.

All times in this Investigation Report are in Hong Kong Local Times unless otherwise stated.

Hong Kong Local Time is Coordinated Universal Time (UTC) + 8 hours.

Chief Accident and Safety Investigator

Air Accident Investigation Authority

Transport and Logistics Bureau

Hong Kong

October 2022

Synopsis

On 26 February 2017, a Cessna 152 aircraft, registration B-HHN of the HKAC took off from the Shek Kong Airfield at about 1032 hours.

Two pilots were on board the aircraft. The pilot in command (PIC) was the examiner; the second pilot was the student. The purpose of the flight was an Aircraft Rating (AR) flight test carried out by the PIC on the student pilot.

The flight was uneventful with the student pilot operating the aircraft until overhead Tolo Channel in the New Territories when the pilots noticed there was an engine problem. The PIC then took control of the aircraft and informed Air Traffic Control (ATC) of the "rough engine" at about 1109 hours.

About one minute later, the PIC advised ATC that "the engine seems to be okay" and that he intended to return to the Shek Kong Airfield. At about 1113 hours, the PIC informed ATC that the engine condition had deteriorated with the intention to attempt a forced landing near the golf driving range of Garden Farm Golf Centre at Sam Pui Chau.

The PIC carried out the forced landing at about 1114 hours. The aircraft collided with various flora and trees adjacent to the golf driving range. The aircraft sustained major damage resulting from the collision with the trees. Nevertheless, both pilots were not injured.

ATC notified the Accident Investigation Division of the CAD shortly after the accident. The investigation was transferred to the AAIA after its establishment in September 2018.

The investigation team has made one safety recommendation.

Contents

1. FACTUAL INFORMATION

1.1. History of the Flight

The purpose of the flight was an AR flight test conducted by the PIC[1]. There were two pilots on board the aircraft, with the PIC on the right-hand seat and the student pilot on the left-hand seat.

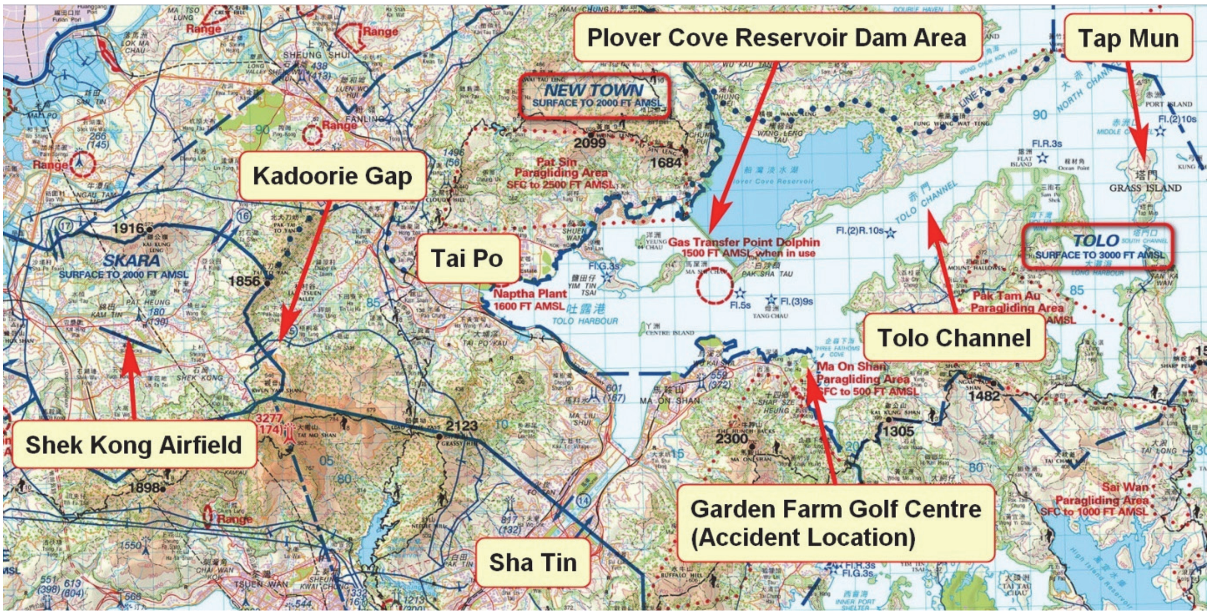

Figure 1: Location of the Accident Site

1.1.1. Preparation of Flight

(1) Flight preparation was done by the student pilot and was part of the AR flight test, which included checking the weather reports and forecast, the Notice to Airmen (NOTAM), and filing of the CAD Local VFR[2] Notification Form (Flight Notification) to the Air Traffic Control Centre advising of a one-hour flight duration with three hours endurance.

(2) Shek Kong Airfield was the departure and arrival aerodrome.

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[1] An examiner authorised by the CAD

[2] Visual Flight Rules (VFR)

(3) The PIC and the student pilot conducted the pre-flight check as per the HKAC procedures.

(4) The pilots performed the fuel content and contamination verification before the flight. The indicated fuel quantity was approximately 22 to 23 US Gallons.

1.1.2. Departure, Climb and Transit Phases

(1) The aircraft took off at approximately 1032 hours from Runway 11. Both pilots stated that the engine performance at take-off was normal.

(2) The departure from Shek Kong Airfield and climb-out via Kadoorie Gap were uneventful. The visibility reported was 7 km.

(3) The flight entered Uncontrolled Airspace Reporting Area (UCARA) New Town from Kadoorie Gap at approximately 1043 hours. At around 1045 hours, the aircraft was at UCARA Tolo starting to climb to approximately 2,700 feet towards the vicinity of Tolo Channel for conducting the AR flight test.

1.1.3. Aircraft Rating Flight Test

According to the interview statements provided by both pilots, the student pilot performed the flight test items as required, including Steep Turn, Slow Flight, Stall, and Unusual Attitude Recovery. Both pilots described that the engine performance was normal during the above manoeuvers, the student pilot emphasised that carburettor heat was applied every time when the engine was in low power setting.

1.1.4. Engine Malfunction

After completion of the above test items near Tap Mun area, both pilots noticed the aircraft engine was producing abnormal noise and engine vibration. The engine then seemed to run smooth again but after less than 1 minute, the engine vibration reoccurred. The student pilot reported that he had applied carburettor heat on immediately and the PIC took control of the aircraft and turned the aircraft back towards Tai Po area.

1.1.5. Inflight Turn Back to Shek Kong Airfield

(1) During the transit back to Shek Kong Airfield, ATC received reporting from the PIC at 1109 hours as follows: -

11:09:23 from B-HHN: "HN we might have an engine problem…. Outside Tap Mun area."

11:09:30 from ATC: "HN Roger. What assistance would you be requiring?"

11:09:34 from B-HHN: "We are trying to proceed back to the Dam area[3]."

11:09:41 from ATC: "Roger. Are you able to do that?"

11:09:42 from B-HHN: "We are…We have a little bit of rough engine but now it's still running okay."

(2) At 1110 hours, at ATC's request, the PIC reported that their "exact location is on Tolo Channel heading westbound towards the Dam area."

(3) At 1111 hours, ATC further asked the pilots if they were able to make a landing back at Shek Kong Airfield as soon as possible, and the PIC replied "we are proceeding that direction, right now the engine seems to be okay", advising ATC that they were trying to climb as high as possible to get more gliding distance.

(4) Both pilots reported during the interview that they had performed engine checks in accordance with the Pilot's Operating Handbook (POH) but there was no improvement of the engine performance. The PIC remarked, "While increasing power for the climb, the engine ran rough again." The PIC immediately reduced the power. However, the engine continued to run rough.

(5) At this moment, the aircraft was over water and abeam Garden Farm Golf Centre.

1.1.6. Forced Landing

(1) At around 1113 hours, ATC received reporting from the PIC, "Cessna HN now... we are going to approach probably to the golf driving range… (三杯酒[4])."

(2) ATC asked the pilots "HN that is copied. Are you able to make a landing?"

[3] The dam area of the Plover Cove Reservoir
[4] The Chinese name of Sam Pui Chau

(3) The PIC replied that "Yea …. See if you can call them and clear the area … we are landing ASAP."

(4) ATC further asked the pilots "HN, confirm emergency landing at the golf range."

(5) The PIC replied, "That's affirmative."

Figure 2: Radar Plot of the Flight Sequence

Figure 3: Garden Farm Golf Centre at Sam Pui Chau

(6) The PIC did not recall the altimeter reading or other panel readings such as engine gauges during the base and final approach manoeuvre, his focus was on conducting the forced landing safely.

(7) The aircraft was too high on the base leg. The PIC extended the flap from 0° to 30°, reducing speed.

(8) When turning final, the PIC noticed that the aircraft was still high and carried out left side-slipping which reduced the height above the ground by 100 to 200 feet, and subsequently a couple of S-turns to further reduce the height of aircraft from the ground.

(9) In the short final stage overhead the driving range, the height of aircraft was around 20 to 30 feet above ground. The PIC noted that the 250 yards driving range was insufficient for a safe landing. The PIC further reduced the height while making a power off descent aiming for the tree line adjacent to the golf driving range.

(10) At about 1114 hours, the aircraft contacted with and rested in the trees, about five to six metres above the ground.

1.2. Injuries to Persons

The two pilots were uninjured during the accident.

Injuries to Persons						
Persons on board:	Crew	2	Passengers	0	Others	0
Injuries	Crew	0	Passengers	0		

Table 1: Injuries to Persons

1.3. Damage - Aircraft

(1) The aircraft sustained substantial damage during the forced landing.

(2) After the accident, a large volume of fuel remained in the aircraft fuel tanks. The remaining fuel was removed to facilitate the relocation of the wreckage and fuel sample analysis.

1.4. Other Damages

There was minor incidental damage associated with the forced landing into a woodland area.

1.5. Personnel Information

The two pilots were licensed and qualified for the flight in accordance with the existing regulations. Their licence details are in Section 6.2 Pilot Information.

1.6. Aircraft Information

1.6.1. Aircraft

Cessna 152 is an all-metal, two-place, high-wing, single-engine aeroplane equipped with fixed pitch propeller and fixed tricycle landing gear. The construction of the fuselage is a conventional formed sheet metal bulkhead, stringer, and skin design referred to as semi-monocoque.

1.6.2. Engine

(1) The aircraft was equipped with a Lycoming O-235 four-cylinder, air-cooled, horizontally opposed piston aircraft engine producing 100 to 135 hp (75 to 101 kW).

(2) The engine is carburettor-equipped with dual magneto ignition and has a displacement of 233 cubic inches (3.82 L).

1.6.3. Aircraft Details

The aircraft was registered in Hong Kong and had a valid Certificate of Airworthiness. Further details of the aircraft are in Section 6.3 Aircraft Details.

1.6.4. Maintenance History

(1) The most recent scheduled maintenance check was a 50-hour inspection carried out on 6 January 2017.

(2) At the time of that inspection, the airframe had accumulated 17,253 hours and the engine had accumulated 2,350 hours since overhaul.

(3) A review of the aircraft records indicated that the aircraft had no outstanding defects prior to the accident flight.

(4) The maintenance records indicated that the aircraft was equipped and maintained in accordance with existing regulations and approved procedures.

1.6.5. Fuel On-board

(1) The aircraft was loaded with fuel sufficient for the intended AR flight test.

(2) The pilots did not observe any sign of fuel loss during flight.

(3) Following the forced landing into the trees, a large volume of fuel remaining in the fuel tanks was drained for further analysis.

1.7. Meteorological Factors

(1) The Sha Tin Automatic Weather Station of the Hong Kong Observatory (HKO) is in close proximity to the crash site. The weather conditions measured by the station at 1030 hours were recorded below:

Sha Tin Automatic Weather Station	
Temperature:	12.8 ºC
Dew Point:	7.5 ºC
Relative Humidity:	70%
Wind Direction / Speed:	040° / 10 knots (weather forecast for Local Aviation issued at 0930 hours for 2,000 feet)
Visibility:	7 km, tempo 4,000 meters in rain (weather forecast for Local Aviation issued at 0930 hours)
Weather:	Mainly cloudy with a few rain patches (weather forecast for local aviation issued at 0930 hours)

Table 2: Weather Conditions

(2) The weather conditions were within the limits for VFR operations.

1.8. Navigation Aids

(1) The accident flight operated in daylight under VFR, during which the aircraft was required to remain clear of cloud and in sight of the surface.

(2) Visual contact with the surface was the principal method of navigation.

(3) The accident aircraft was equipped with appropriate navigation equipment for the flight.

1.9. Communications

(1) The accident site was located in one of the seven UCARAs known as "New Town".

(2) Hong Kong Aeronautical Information Publication issued by the CAD refers to UCARAs as Class G airspace. Aircraft operating in UCARAs are required to maintain a two-way radio communication with ATC on the designated VHF[5] frequency 121.0 MHz for the traffic information service.

(3) The accident aircraft was equipped with a serviceable VHF radio and in communication with ATC.

1.10. Aerodrome Information or Remote Accident Location

The accident location was adjacent to the B course driving range of Garden Farm Golf Centre at Sam Pui Chau, New Territories, Hong Kong.

1.11. Flight Recorders

The regulatory requirements in Hong Kong do not stipulate that this category of aircraft shall be equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR).

1.12. Wreckage and Impact

The aircraft was in the tree line and the outboard section of the left wing had separated from the fuselage with the main aircraft assembly embedded into the trees.

[5] Very High Frequency

Photo 1: Aircraft Location (Ground View)

Photo 2: Aircraft Location (Aerial View)

1.13. Medical/Pathological Information

Both pilots were uninjured.

1.14. Smoke, Fire, and Fumes

There was neither fuel leakage nor fire.

1.15. Survival Aspects

1.15.1. Search and Rescue

1.15.1.1. Locating the Aircraft by Government Flying Service (GFS)

(1) A GFS helicopter was operating in the area when the PIC of the accident aircraft reported its "rough engine" to ATC.

(2) The crew of the GFS helicopter visually identified the accident aircraft and observed the forced landing into the trees.

(3) The pilot of the GFS helicopter then immediately made a "MAYDAY" call and advised ATC that the accident aircraft had crashed into the trees. ATC then reported the accident to the "999" Emergency Call Service.

1.15.1.2. Evacuation Assisted by the Fire Services Department (FSD)

(1) FSD vehicles arrived at Garden Farm Golf Centre at 1135 hours; a rescue team reached the accident site about five minutes later.

(2) The two pilots were assisted from the cockpit of the aircraft at about 1150 hours.

1.15.2. Certification – Emergency Exits, Crew Protection, and Fire Protection

Certification of the aircraft is compliant with the State of Manufacture and Design's Code of Federal Regulations (CFR) Part 23:

PART 23 — AIRWORTHINESS STANDARDS: NORMAL CATEGORY AIRCRAFT

§23.2315 Means of egress and emergency exits.

- *With the cabin configured for take-off or landing, the aircraft is designed to:*

- *Facilitate rapid and safe evacuation of the aircraft in conditions likely to occur following an emergency landing, excluding ditching for level one; level two and single engine level three aircraft.*
- *Have means of egress (openings, exits or emergency exits), that can be readily located and opened from the inside and outside. The means of opening must be simple and obvious and marked inside and outside the aircraft.*
- *Have easy access to emergency exits when present.*

§23.2320 Occupant physical environment.

The applicant must design the aircraft to —

- *Allow clear communication between the flight crew and passengers;*
- *Protect the pilot and flight controls from propellers; and*
- *Protect the occupants from serious injury due to damage to windshields, windows, and canopies.*

§23.2325 Fire protection.

- *Each area where flammable fluids or vapours might escape by leakage of a fluid system must —*
- *Be defined; and*
- *Have a means to minimize the probability of fluid and vapour ignition, and the resultant hazard, if ignition occurs.*

1.16. Tests and Research

1.16.1. Engine Run and Engine Examination

(1) As the pilots reported engine roughness, the engine was sent for additional testing and inspection in the United States of America (USA).

(2) The engine run and engine examination were coordinated and supervised by the NTSB, performed by a third party organisation in Seattle, and attended by the CAD.

1.16.2. Fuel

Fuel samples collected from the aircraft's fuel tanks were secured, quarantined, and sent for independent analysis.

1.17. Organisation, Management, System Safety

1.17.1. Civil Aviation Department

(1) The CAD regulates the HKAC as a flying club based on the Air Navigation (Hong Kong) Order 1995 (Cap. 448C).

(2) The CAD conducted regular audits and inspections on the non-public transport flight operations and aircraft maintenance standards of the HKAC.

(3) The CAD has a Hong Kong Aviation Safety Programme (HKASP) to introduce performance-based regulatory elements in safety oversight to focus on relatively higher risk areas based on all available information, and seek assurance that those risks are proactively mitigated through effective means. 'Smaller' aircraft accident is one of the safety indicators under the HKASP.

1.17.2. Hong Kong Aviation Club

(1) The HKAC is a private members club operating from Shek Kong Airfield.

(2) As a private members club, under the current legislation, the HKAC is not required to hold a flying training organisation approval issued by the CAD for its operations.

1.17.2.1. Operations

(1) The HKAC conducts flying training courses for Private Pilot's Licence (PPL) and Assistant Flight Instructor's (AFI) rating.

(2) Its operations staff under the direction of the General Committee manage the day-to-day operations.

(3) It is an HKAC's requirement on the aircraft Flight Authorisation Log (FAL) that prior to each flight all pilots certify that their aircrew licences are valid and that they have read and understood all relevant flying notices, orders and NOTAMs.

(4) Local aviation weather forecast and reports (METAR/SPECI) issued by the HKO are reviewed by pilots during flight preparation.

1.17.2.2. Engineering

The HKAC's Engineering Department has licensed aircraft engineers and technicians to maintain the aircraft of the HKAC and its members.

1.17.2.3. Communicating the Hazards of Carburettor Icing to Pilots

According to the HKAC, the dissemination of the hazards of carburettor icing to their pilots were covered in the Club's Private Pilot's Licence flight training briefs, the POH for the relevant aircraft (e.g. 3-13 of C152 POH) and as part of the annual flight review for all pilots. The following were in place at the time of the occurrence:

1.17.2.3.1. Pre-flight Briefings

The pre-flight briefings are used as part of the HKAC's initial training for PPL, recurrent training, and annual flight reviews (AFR). They include a number of sections related to carburettor icing. More specifically, slide 8 of the briefings calls for the periodic application of carburettor heat as part of the regular enroute checks, and slide 31 (Exercise 17a - Forced Landings without Power) lists carburettor icing as one of the potential causes of engine failure and calls for the application of carburettor heat as one of the troubleshooting items (i.e., "CH – HOT").

1.17.2.3.2. Instructor Check List for Annual Flight Review and Self Authorization Check Flights

The check list includes a specific item covering Exercise 17a for practice of forced landings without power.

1.17.2.3.3. General Flying Order GFO-02 and Pilot's Operating Handbook

The HKAC's GFO-02 'Pilot Operating Handbook' requires all pilots to operate the HKAC's aircraft according to the instructions contained in the relevant POH, and accordingly, pilots are routinely reminded to review the POH of the aircraft they fly, with an emphasis on regular reviews of the emergency procedures. Section 3-13 in the emergency procedures section of the POH for the Cessna 152 sets forth the factors to identify carburettor icing (i.e., "gradual loss of engine RPM[6] and eventual engine roughness"), as well as procedures for how to address carburettor icing (i.e., "apply full throttle and pull the carburettor heat knob full out until the engine runs smoothly").

[6] Revolution(s) Per Minute

1.17.2.3.4. Ground School Course

The HKAC's ground school course includes a module on Aviation Weather, which also specifically covers carburettor icing, including a reminder that pilots should use carburettor heat as set forth in the POH and a discussion of the exact conditions under which carburettor icing can occur (i.e., outside temperature between -6°C to +26°C with high relative humidity).

1.17.2.4. Safety Management System

(1) The HKAC was not mandated by Cap. 448C[7] to develop a risk-based Safety Management System (SMS). However, they had been encouraged by the CAD to develop one.

(2) At the time of the accident, their SMS Manual was last updated on 18 November 2016. Several sections were annotated with "under construction", "to be implemented", or "Not yet assigned".

(3) The HKAC SMS Manual was re-written in accordance with CAD 712[8] and reissued in November 2020. It received a letter of "no further comment" from the CAD. Some SMS trainings for staff have already been completed.

1.17.3. General Flying Orders

(1) The HKAC publishes GFOs which are mandatory for all pilots operating fixed-wing aircraft owned by the HKAC. The GFOs also apply to pilots operating privately owned fixed-wing aircraft based at the HKAC.

(2) The GFOs may only be issued, amended or cancelled by the Chief Flying Instructor (Aeroplanes). The HKAC requires pilots to read, understand and sign the GFOs every 12 months and whenever a new GFO is published.

(3) New GFOs would be placed on the notice board in the Shek Kong Operations Room for a month, after which they would be inserted into the Flying Order Book (FOB). Current GFOs are contained in the FOB and could also be downloaded from the HKAC website by members.

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[7] Article 102 of Cap. 448C is the statutory requirement on who shall implement an SMS and what is to be complied with.

[8] CAD 712 Safety Management Systems (SMS) for Air Operators and Maintenance Organizations, A Guide to Implementation

(4) GFO-02 requires that 'all pilots must operate the aircraft according to the instructions contained in the Pilot Operating Handbook (POH); where the HKAC procedures differ from the POH the pilot must be familiar with these differences and operate the aircraft in accordance with the POH'.

1.17.4. Safety Management System

(1) An SMS is a systematic approach to managing safety, including the necessary organisational structures, accountability, responsibilities, policies and procedures.

(2) This systematic and explicit approach defines the activities by which safety management is undertaken by an organisation in order to achieve an acceptable level of safety.

(3) The objective of an SMS is to provide a structured approach to safety risks control in operations. The organisation's specific structures and processes related to safety of operations must be taken into account in the effective safety management.

(4) The SMS development begins with setting the organisational safety policy, safety planning and the implementation of safety management procedures are the next key steps in the processes designed to mitigate and contain risk in operations.

(5) An effective SMS should include the following in content and structure:

a) A process identifying actual and potential safety hazards and assessing the associated risks;

b) A process developing and implementing remedial action necessary to maintain an acceptable level of safety; and

c) Provisions for continuous monitoring and regular assessment of the appropriateness and effectiveness of safety management activities.

(6) The ICAO Safety Management Manual (SMM) (Doc 9859) contains detailed guidance on the implementation of an SMS.

(7) The framework for an SMS can be found in ICAO Annex 19 Safety Management.

Figure 4: ICAO Annex 19/Safety Management

(8) The concept of SMS can be simply summarised as[9]:

- Actively look for safety issues in operations, products, or services;
- Develop corrective actions to reduce the risks those safety issues present; and
- Monitor to be sure that those risks have been appropriately controlled.

1.18. Additional Information

1.18.1. Engine Carburettor Heating Schematic

(1) The engine was carburettor-equipped with carburettor heat control.

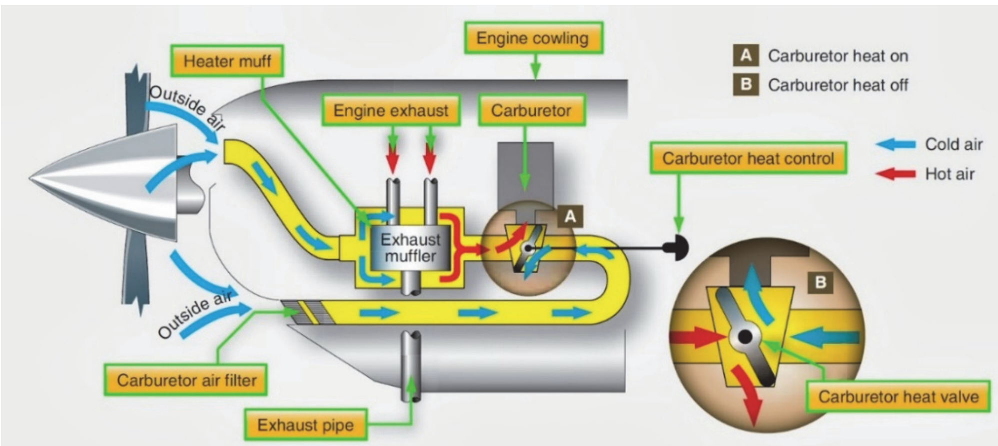


Figure 5: Typical Carburettor Heating Airflow and Heat Exchanger[10]

[9] SMS for Small Organizations, Safety Management International Collaboration Group (SM ICG), March 2015

[10] Source: https://www.aircraftsystemstech.com/2017/06/types-of-aviation-fuel.html

(2) This air preheater is essentially a tube or jacket through which the exhaust pipe from one or more cylinders passes through. The air flowing over these surfaces increases to the required temperature before entering the carburettor.

1.18.2. Carburettor Icing[11]

1.18.2.1. Cause of Carburettor Icing

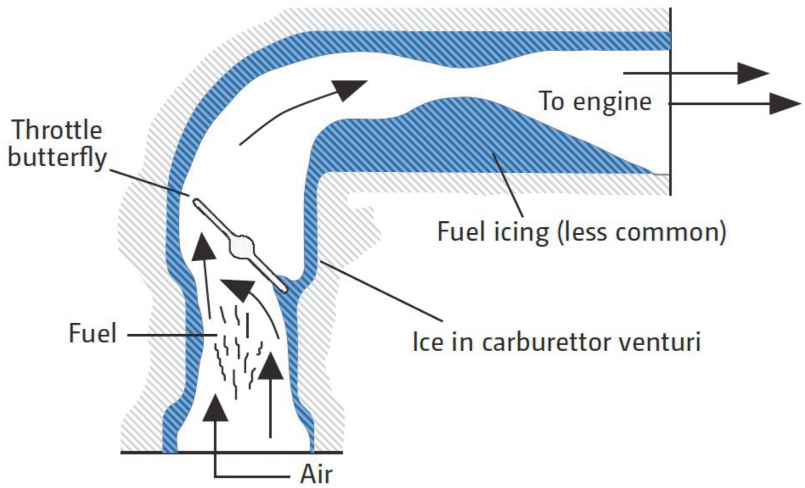


Figure 6: Build-up of Icing in Induction System

(1) Piston engine induction system icing is commonly referred to as carburettor icing. The most common, earliest to show, and most serious, is carburettor icing caused by a combination of sudden temperature drop due to fuel vapourisation and pressure reduction necessary for fuel suction and atomisation as the mixture passes through the carburettor venture, which provides the Bernoulli effect for suction, and past the throttle valve.

(2) If the temperature drop brings the air below its dew point, condensation results, and if the drop brings the mixture temperature below freezing point, the condensed water will form ice on the surfaces of the carburettor. This ice gradually blocks the venturi, which upsets the fuel / air ratio causing a progressive, smooth loss of power and slowly ‘strangles’ the engine, i.e. the phenomenon of engine roughness.

[11] Source: *Piston Engine Icing, SafetySense Leaflet 14 Version B, UKCAA*

1.18.2.2. Use of Carburettor Heat Control

(1) Under certain moist atmospheric conditions (generally at a relative humidity of 50% or greater) and at temperatures of 7° to 32° C (45° to 90°F), it is probable for ice to form in the induction system.

(2) Even in summer weather ice may form - this is due to the high air velocity through the carburettor venturi and the absorption of heat from this air by vapourisation of the fuel.

(3) The temperature in the mixture chamber may drop as much as 21°C (70°F) below the temperature of the incoming air. If this air contains a large amount of moisture, the cooling process can cause precipitation in the form of ice. Ice formation generally begins in the vicinity of the butterfly valve and may build up to such an extent that a drop in power output could result.

(4) In installations equipped with fixed pitch propellers, a drop in RPM reflects a loss of power. In installations equipped with constant speed propellers, a drop in manifold pressure reflects a loss of power. If not corrected, this condition may cause complete engine stoppage.

(5) To avoid this, all installations are equipped with a system for preheating the incoming air supply to the carburettor. In this way, sufficient heat is added to replace the heat loss of vapourisation of fuel, and the mixing chamber temperature cannot drop to the freezing point of water 0°C (32°F). The exhaust pipe from one or more cylinders is passed through the preheater, and the air flowing over these surfaces is raised to the required temperature before entering the carburettor.

(6) This will result in a slight additional drop in manifold pressure, which is normal, and this drop will be regained as the ice is melted out of the induction system. When ice has melted from the induction system, the carburettor heat control can be returned to the full cold position.

1.18.3. Safety Information on Carburettor Icing

(1) The Civil Aviation Authority of the United Kingdom (UKCAA) issued a document titled *Piston Engine Icing, SafetySense Leaflet 14 Version B* in January 2013 (Appendix 9.1). The Leaflet provides comprehensive advice and guidance on how to recognise and avoid carburettor icing.

(2) Contrary to common understanding, “carb icing is not restricted to cold weather. It will occur on warm days if humidity is high,” Furthermore, the UKCAA document indicates in a carburettor icing probability predictive

chart that under certain combination of ambient conditions, carburettor icing may become serious and affect the engine operation on any power setting.

(3) In the presence of certain ambient conditions, the UKCAA document recommends that “Hot air should be selected as a matter of routine, at regular intervals to prevent ice build-up…Carburettor heat should be applied at regular intervals, to prevent carburettor ice forming…Carburettor heat should be applied early enough before descent to warm the intake, … and use full carb hot air frequently when flying in conditions where carb icing is likely.”

1.19. Useful or Effective Investigation Techniques

Not applicable in this investigation.

2. Safety Analysis

The Safety Analysis provides a detailed discussion of the safety factors identified during the investigation, providing the evidence required to support the findings, contributing factors and the safety recommendations.

2.1. Weather Forecasts

(1) Aviation weather forecasts do not normally include specific warnings of induction system icing. Pilots' knowledge and experience are important to determine the risk of encountering engine icing conditions.

(2) Dew point readings close to the mean temperature are an indication that the relative humidity is high. However, the humidity reported at an aerodrome may bear little relation to the humidity at flying altitudes.

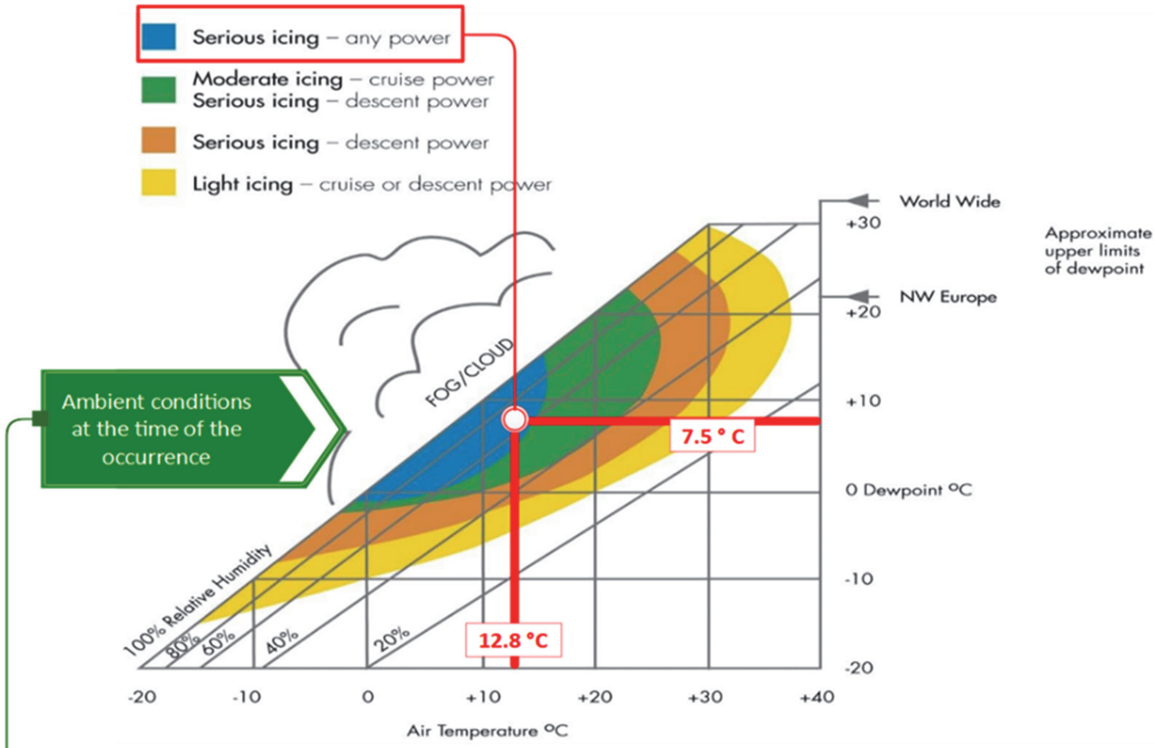
(3) The student pilot checked weather reports and the forecasts as part of the flight preparation.

(4) The information in both the weather reports and the forecasts was considered within the limits prescribed by the Air Navigation (Hong Kong) Order 1995 for operations under VFR.

2.2. Carburettor Icing

2.2.1. Risk of Carburettor Icing

Figure 7 is based on the carburettor icing probability predictive chart, which shows the wide range of ambient conditions in which carburettor icing is most likely, in the UKCAA document. The combination of temperature (12.8 ºC), dew point (7.5 ºC) and relative humidity (70%), as reported around the time the aircraft was airborne, indicate a serious carburettor icing risk at any power.



Sha Tin Automatic Weather Station	
Temperature:	12.8 °C
Dew Point:	7.5 °C
Relative Humidity:	70%
Wind Direction / Speed:	040° /10 knots (weather forecast for local aviation issued at 0930 hours for 2,000 feet)
Visibility:	7 km, tempo 4,000 meters in rain (weather forecast for local aviation issued at 0930 hours)
Weather:	Mainly cloudy with a few rain patches (weather forecast for local aviation issued at 0930 hours)

Figure 7: Carburettor Icing Vs Ambient Conditions[12]

2.2.2. Recognition of Carburettor Icing

According to the UKCAA Leaflet, with a fixed pitch propeller, a slight drop in RPM and performance (airspeed and/or altitude) are the most likely indications of the onset of carburettor icing. This loss of engine speed, indicated in RPM, can be smooth and gradual and the usual reaction is to open the throttle slightly to compensate. However, this, whilst restoring power, hides the loss. As icing builds up, rough running, vibration, further loss of performance and ultimately engine stoppage may

[12] Source: *Piston Engine Icing, SafetySense Leaflet 14 Version B, UKCAA*

follow. The primary detection instrument is the engine RPM gauge in conjunction with airspeed indicator and altimeter.

2.2.3. Carburettor Heat Checks

(1) According to the interview statements, both pilots described that the engine performance was normal during the AR flight test, the PIC and the student pilot emphasized that full carburettor heat was applied every time when the engine was in low power setting. At the last test item, the student pilot was requested to perform another unusual attitude recovery test, the engine RPM was set at the green arc minima without carburettor heat applied. After the unusual attitude recovery, they noticed that the aircraft engine was producing abnormal noise and engine vibration without experiencing any slight drop in RPM after completion of the above test near Tap Mun area. After the engine seemed to run smooth again, the engine vibration reoccurred after less than one minute. The student pilot indicated that he had applied carburettor heat on immediately and the PIC took control of the aircraft.

(2) It was possible that carburettor icing occurred during this flight manoeuvre.

(3) According to *Piston Engine Icing, SafetySense Leaflet 14*, carburettor body heat should be selected whenever carburettor icing is likely. Hot air should be selected as a matter of routine, at regular intervals to prevent ice build-up; whenever a drop in RPM, or rough engine running, is experienced; when carburettor icing conditions are suspected; and when flying in conditions within the high probability ranges indicated in the chart.

(4) In addition, during the cruise, carburettor heat should be applied at regular intervals to prevent carburettor ice forming. If a hot air system is fitted, a carburettor heat check should be performed at least every 10 minutes and more frequently if conditions are conducive to icing.

2.3. Forced Landing and Choices of Site

(1) During the interview, the PIC advised that when the engine malfunctioning reoccurred, he considered three options as listed below:

Options	Considerations
Returning to Shek Kong Airfield	The transit to Shek Kong Airfield via Kadoorie Gap required a minimum height above ground clearance. The track to the Kadoorie gap also required flying over built up residential areas of Tai Po Town.
Landing on the Plover Cove Reservoir Dam	The problem was that the dam would be crowded with people on Sunday.
Landing on the driving range of the Garden Farm Golf Centre	The golf driving range was a flat field without built-up area and the rescue services could easily access it. In addition, there would be no persons on the range.

Table 3: Options of Forced Landing

(2) He eventually decided to perform a forced landing without power onto the driving range of Garden Farm Golf Centre. He then advised ATC of his intention and proceeded to the golf centre.

(3) In addition to the three options above, the other option was to ditch in the area but survival from a ditching can be sometimes doubtful. Often the occupants will survive the ditching but either get trapped in the wreckage as it sinks or drown after exiting the aircraft.

(4) As the engine was ‘running roughly’ and not developing full power once the PIC realised that the aircraft was too high to land on the driving range. The possibility exists that if the pilot tried to go around on limited power, a loss of control might have resulted due to the aircraft performance being downgraded. This might have led to a stall/spin scenario with limited survival possibilities. He probably then considered that the alternative was to ‘fly’ the aircraft under control, land in the trees, and let the trees absorb the impact at that stage.

(5) At that stage with the engine running roughly, the PIC would have had very little options. The choice of the flat driving range for landing was considered appropriate.

2.4. Engineering

2.4.1. Aircraft Maintenance

The maintenance records indicated that the aircraft was equipped and maintained in accordance with existing regulations and approved procedures, indicating that prior to the accident flight the aircraft had no outstanding defects which could contribute to this accident.

2.4.2. Engine Run and Examination

(1) As the engine performance was a factor in the occurrence, the engine was transported to the USA for an independent inspection.

(2) During the live engine run, the engine performed according to specifications.

(3) During the subsequent engine examination, no evidence of a contributing mechanical malfunction was detected.

2.5. Fuel

2.5.1. Fuel Sample Test

(1) The laboratory analysis on fuel samples, collected from the aircraft fuel tanks after the accident, indicated that they met the specifications of Avgas 100LL with no contamination, except the Tetraethyl Lead (TEL) contents.

(2) The TEL in the fuel samples was at 0.90 gPb/L (left hand wing tank) and 1.00 gPb/L (right hand wing tank), and exceeded the maximum limit of 0.56 gPb/L.

(3) According to the Certificate of Quality of the Avgas 100LL supplied to the HKAC, the listed TEL content was within the limit.

2.5.2. Engine Manufacturer's Service Instruction on Fuel Specifications

(1) Lycoming, the engine manufacturer, stated in Service Instruction No. 1070AB (Appendix 9.2) that “Continuous use of high lead fuels can cause increased lead deposits both in combustion chambers and spark plugs causing roughness in engine operation and scored cylinder walls.”

(2) The independent engine examination did not identify any evidence of stuck exhaust or intake valves or any lead fouling on the spark plugs that might have caused engine roughness resulting from TEL exceedance.

2.6. Post-Accident Cold Weather Operation Information Issued by the HKAC

(1) After the accident, the HKAC posted information on Cold Weather Operation in March 2017. The information advised the club members that “It has come to that time of the year again near Feb-April when temperatures are typically between 16-20°C and humidity is the highest at more than 80%. Such conditions are highly conducive to carburettor icing and we urge members take special care during engine carb ice checks and when operating at low RPM.”

(2) Given the ambient conditions under which carburettor icing is very likely to occur, the limited scope of the post-accident advisory information was open to interpretation that the risk of carburettor icing would only occur when operating at low engine RPM.

(3) On 1 September 2019, the HKAC issued a new General Flying Orders GFO-34 ‘Carburetor Heat Check’ which included the relevant information on regular application of carburettor heat as contained in *UKCAA SafetySense Leaflet 14 Version B*.

2.7. Application of SMS in the HKAC

(1) The HKAC issued a fully-revised SMS Manual in November 2020, and some of the staff training on SMS have been completed. Their SMS will take time to mature and the aim should be to maintain or continuously improve the safety performance of the organisation.

(2) The carburettor heat information, as described from paragraphs 1.17.2.3.1 to 1.17.2.3.4, disseminated the hazards of and actions against carburettor icing. However, without additional comprehensive advice and guidance, such as *UKCAA SafetySense Leaflet 14*, one may not be able to assess the risk in certain ambient conditions which were conducive to serious carburettor icing, and take appropriate mitigation measures.

(3) The principles of SMS can be applied to thoroughly review their operations, such as conducting an AR flight test in ambient conditions conducive to serious carburettor icing, in order to identify safety hazards, assess the risk associated with a given hazard, recommend steps to mitigate the hazard, and disseminate safety information to the HKAC community.

3. Conclusions

3.1. Findings

(1) The flight crew were licensed and qualified for the flight in accordance with the existing regulations. (1.5)

(2) The aircraft was certified, equipped and maintained in accordance with the existing regulations. [1.6.3, 1.6.4 (4)]

(3) The fuel quantity was sufficient for the flight. [1.6.5 (1)]

(4) There was no evidence of any fuel loss during the flight. [1.6.5 (2) and 1.6.5 (3)]

(5) The regulatory requirements in Hong Kong do not stipulate that this category of aircraft shall be equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR). (1.11)

(6) The HKAC was not mandated by Cap. 448C to develop a Safety Management System (SMS). However, they had been encouraged by the CAD to develop one and implemented it voluntarily. [1.17.2.4 (1)]

(7) The weather conditions were within the limits for VFR operations. [2.1 (4)]

(8) The engine operation was vulnerable to serious carburettor icing at any power setting given the prevailing ambient conditions. (2.2.1)

(9) At the last test item of performing another unusual attitude recovery test, the engine RPM was set at the green arc minima without carburettor heat applied. After the unusual attitude recovery, the pilots noticed that the aircraft engine was producing abnormal noise and engine vibration after completion of the above test near Tap Mun area. It was possible that carburettor icing occurred during this flight manoeuvre. [2.2.3 (1) and 2.2.3 (2)]

(10) The forced landing was inevitable based on the variable engine operating conditions. The choice of the flat driving range for landing was considered appropriate. [2.3 (1) and 2.3 (5)]

(11) There was no evidence of any aircraft defects and mechanical malfunction of engine which could contribute to the accident. (2.4.1 and 2.4.2)

(12) The fuel samples were of the required grade and quality with no contamination, except that the contents of Tetraethyl Lead exceeded the published maximum limit of Avgas 100LL. [2.5.1 (1) and 2.5.1 (2)]

(13) There was no evidence of stuck exhaust or intake valves or any lead fouling on the spark plugs that might have caused engine roughness resulting from TEL exceedance. [2.5.2 (2)]

(14) Although the HKAC disseminated the hazards of and actions against carburettor icing to the members as training and safety information, there was a lack of comprehensive advice and guidance on how to assess the risk in certain ambient conditions which were conducive to serious carburettor icing, and take appropriate mitigation measures. [2.7 (2)]

(15) Without additional comprehensive advice and guidance, such as *UKCAA SafetySense Leaflet 14*, one may not be able to assess the risk in certain ambient conditions which are conducive to serious carburettor icing, and take appropriate mitigation measures. [2.7 (2)]

(16) The investigation team believes that the principles of SMS can be applied to thoroughly review the HKAC operations in order to identify safety hazards, assess the risk associated with a given hazard, recommend steps to mitigate the hazard, and disseminate safety information to the HKAC community. [2.7 (3)]

3.2. Cause

It was possible that the engine running rough was due to carburettor icing, as a result of carburettor heat not selected during the unusual attitude recovery manoeuvre, which resulted in a forced landing. [3.1 (9) and 3.1 (10)]

3.3. Contributing Factor

The engine operation was vulnerable to serious carburettor icing at any power setting given the prevailing ambient conditions. [3.1 (8)]

4. Safety Actions Already Implemented

Whether or not the AAIA identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their risks.

The AAIA has been advised of the following proactive safety action in response to this occurrence.

4.1. Proactive Safety Action by Hong Kong Aviation Club

(1) After the accident, the HKAC posted the information on Cold Weather Operation on their notice board in Shek Kong Airfield in March 2017. The HKAC information states that:

"Such conditions are highly conductive to carburettor icing and we urge members take special care during engine carb ice checks and when operating at low RPM."

(2) A carburettor icing probability chart is also provided and the associated texts further informed that:

"Carburettor heat should be applied fully in conditions where icing is likely. With icing, prevention is easier and more effective than cure."

(3) On 1 September 2019, the HKAC issued a new General Flying Orders GFO-34 'CARBURETOR HEAT CHECK' which included the relevant safety information on regular application of carburettor heat as contained in the *UKCAA SafetySense Leaflet 14 Piston Engine Icing*. The GFOs have later been transcribed into Operations Manual and Training Manual.

(4) Carburettor Icing has been included in their Meteorology Ground Lesson and flight exercises in their Fixed Wing Training Manual and Helicopter Training Manual.

(5) The HKAC SMS Manual was re-written in accordance with CAD 712 and reissued in November 2020. It received a letter of "no further comment" from the CAD. Some SMS trainings for staff have already been completed.

5. Safety Recommendations

5.1. Safety Recommendation 12-2022

It is recommended that the HKAC applies SMS principles to thoroughly review their operations in order to identify safety hazards, assess the risk associated with a given hazard, recommend steps to mitigate the hazard, and disseminate safety information to the HKAC community. [3.1 (16)]

Safety Recommendation Owner: Hong Kong Aviation Club

6. General Details

6.1. Occurrence Details

Date and time:	26 February 2017, 1114 hours (local time)	
Occurrence category:	Accident	
Primary occurrence type:	FUEL: Fuel Related	
Location:	Near Garden Farm Golf Centre, Sam Pui Chau, New Territories, Hong Kong	
	Latitude: 22º25'56.4" N	Longitude: 114º15'59.8" E

6.2. Pilot Information

6.2.1. Pilot-in-Command

Licence details:	Hong Kong Private Pilot's Licence (Aeroplanes)
Endorsements:	Not applicable
Ratings:	Flying Instructor's Rating and CAD authorization to conduct flight tests on Group A aircraft (i.e. single-engine aeroplanes not exceeding 5,700 kg maximum total weight authorized)
Medical certificate:	Valid until 31 March 2017
Aeronautical experience:	1,559.5 hours as at 26 February 2017, of which 920 hours were instructional
Certificate of Experience:	Not applicable
Age:	65

6.2.2. Student Pilot

Licence details:	Hong Kong Private Pilot's Licence (Aeroplanes)
Endorsements:	Not applicable
Ratings:	Not applicable
Medical certificate:	Valid until 31 December 2017
Aeronautical experience:	285.6 hours as at 26 February 2017
Certificate of Experience:	Not applicable
Age:	59

6.3. Aircraft Details

Manufacturer and model:	Textron Aviation Inc. (Formerly Cessna Aircraft Company)/Cessna Model 152
Registration:	Hong Kong, China / B-HHN, issued on 28 June 1982 in the ownership of Hong Kong Aviation Club Limited
Aircraft Serial number:	15279428
Year of Manufacture:	1977
Engine:	One Lycoming O-235-L2C engine
Propeller:	One Sensenich Propeller Manufacturing Company Inc. 72CKS6-0-54 (FAA STC SA1219EA)
Operator:	Hong Kong Aviation Club Limited
Type of operation:	Training
Certificate of Airworthiness:	Issued on 15 December 2016 in the Transport Category (Passenger) and valid until 29 December 2017

Departure:	Shek Kong Airfield	
Destination:	Shek Kong Airfield	
Maximum Approved Gross Weight:	1,670 lbs	
Total Airframe Hours:	17,294 hours	
Persons on board:	Crew – 2	Passengers – Nil
Injuries:	Crew – 0	Passengers – Nil
Aircraft damage:	Major Damage	

7. Abbreviations

AFR	Annual Flight Review
Annex 13	Annex 13 to the Convention on International Civil Aviation - Aircraft Accident and Incident Investigation
AR	Aircraft Rating
ATC	Air Traffic Control
CAD	Civil Aviation Department, Hong Kong
Cap. 448B	Hong Kong Civil Aviation (Investigation of Accidents) Regulations
Cap. 448C	Air Navigation (Hong Kong) Order 1995
Carb	Carburettor
°C	Degrees Celsius
°F	Degrees Fahrenheit
FAL	Flight Authorisation Log
FOB	Flight Order Book
FSD	Fire Services Department
GFO	General Flying Orders
GFS	Government Flying Service
HKAC	Hong Kong Aviation Club
HKO	Hong Kong Observatory
ICAO	International Civil Aviation Organization
METAR	Meteorological Aerodrome Report
MHz	Megahertz
NOTAM	Notice to Airmen

NTSB	National Transportation Safety Board of the United States of America
PIC	Pilot in command
POH	Pilot’s Operating Handbook
PPL	Private Pilot’s Licence
RPM	Revolution(s) Per Minute
SMS	Safety Management System
SPECI	Special weather reports
TEL	Tetraethyl Lead
UCARAs	Uncontrolled Airspace Reporting Areas
UKCAA	The Civil Aviation Authority of the United Kingdom
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency

8. Table of Figures, Photos, Tables

9. Appendices

9.1. Piston Engine Icing, SafetySense Leaflet 14 Version B

Civil Aviation Authority

SAFETYSENSE LEAFLET 14
PISTON ENGINE ICING

1 INTRODUCTION

a) This leaflet is intended to assist pilots of carburetted piston-engined aircraft operating below 10,000 feet. Although it may appear to be mainly aimed at aeroplane operations, much of its content applies at least equally to piston-engined helicopters and gyroplanes.

b) Piston engine induction system icing is commonly referred to as carburettor icing, although, as described later, carb icing is only one form. Such icing can occur at any time, **even on warm days, particularly if they are humid**. It can be so severe that unless **correct** action is taken the engine may stop (especially at low power settings during descent, approach or during helicopter autorotation).

c) Every year engine induction system icing is assessed as being a likely contributory factor in several aircraft accidents. Unfortunately the evidence rapidly disappears.

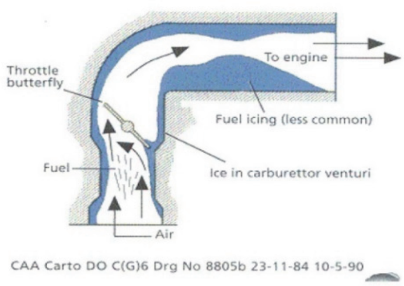
d) Some aircraft/engine combinations are more prone to icing than others and this should be borne in mind when flying different aircraft types.

e) The aircraft Flight Manual or Pilot's Operating Handbook is the primary source of information for individual aircraft. The advice in this leaflet should only be followed where it does not contradict that Flight Manual.

2 TYPES OF ICING

There are three main types of induction system icing:

BUILD-UP OF ICING IN INDUCTION SYSTEM



CAA Carto DO C(G)6 Drg No 8805b 23-11-84 10-5-90

January 2013

www.caa.co.uk/safetysense

a) Carburettor Icing

The most common, earliest to show, and the most serious, is carburettor (carb) icing caused by a combination of the sudden temperature drop due to fuel vaporisation and pressure reduction as the mixture passes through the carburettor venturi and past the throttle valve.

If the temperature drop brings the air below its dew point, condensation results, and if the drop brings the mixture temperature below freezing, the condensed water will form ice on the surfaces of the carburettor. This ice gradually blocks the venturi, which upsets the fuel/air ratio causing a progressive, smooth loss of power and slowly 'strangles' the engine. Conventional float type carburettors are more prone to icing than pressure jet types.

b) Fuel Icing

Less common is fuel icing which is the result of water, held in suspension in the fuel, precipitating and freezing in the induction piping, especially in the elbows formed by bends.

c) Impact Ice

Ice which builds up on air intakes, filters, alternate air valves etc. is called impact ice. It forms on the aircraft in snow, sleet, sub-zero cloud and rain (if either the rain or the aircraft is below 0°C).

This type of icing can affect fuel injection systems as well as carburettors. In general, impact ice is the main hazard for turbocharged engines.

3 ENGINE FACTORS

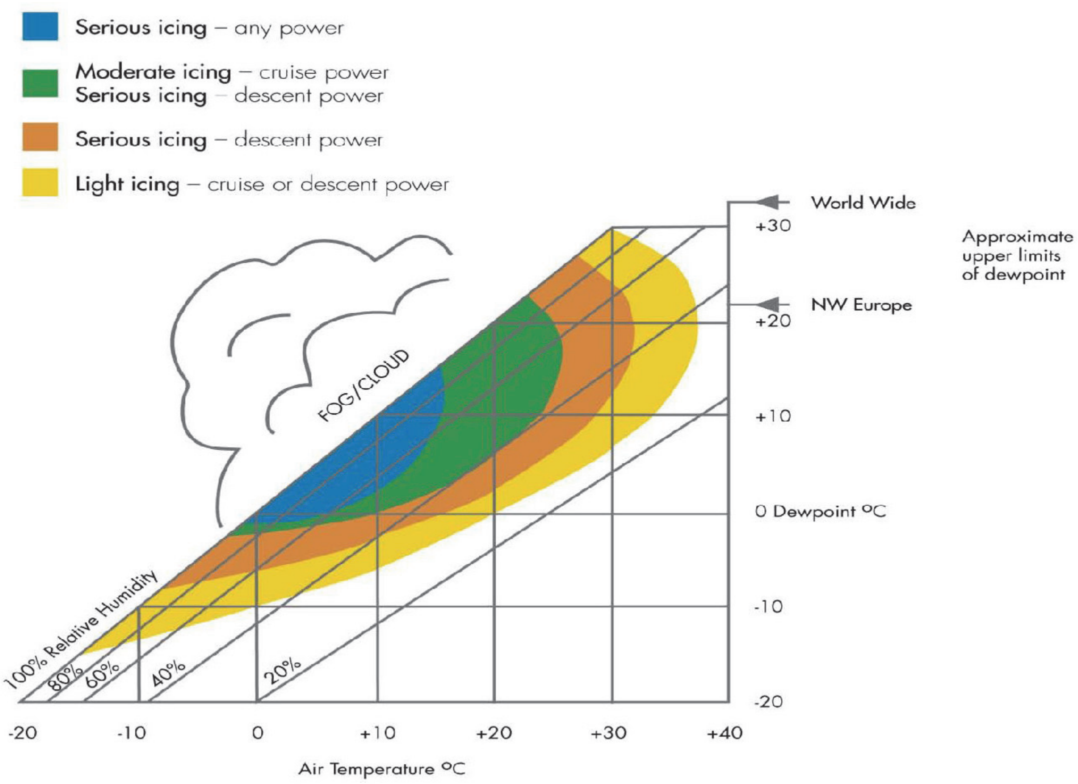
a) Testing has shown that because of its greater and seasonally variable volatility and higher water content, carb icing is more likely when MOGAS is used.

b) Engines at reduced power settings are more prone to icing because engine induction temperatures are lower. Also, the partially closed butterfly can more easily be restricted by the ice build-up. This is a particular problem if the engine is de-rated as in many piston-engined helicopters and some aeroplanes.

c) A rough carburettor venturi surface is also likely to increase carburettor icing severity.

d) Water-cooled engine bodies tend to cool less quickly when power is reduced, reducing the carburettor icing severity. Coolant directed around the carburettor body may maintain the venturi temperature above freezing.

Note: For the sake of simplicity, in the rest of this leaflet, the term 'Carb Icing' is used to cover all Induction Icing, and 'Carb Hot Air' includes Alternate Air.



4 ATMOSPHERIC CONDITIONS

a) Carb icing is **not** restricted to cold weather. It will occur on **warm days** if humidity is high, especially at **low power settings**. Flight tests have produced serious icing at descent power with ambient (not surface) temperature above 25°C, even with relative humidity as low as 30%. At cruise power, icing occurred at 20°C when relative humidity was 60% or more. (Cold, clear winter days are less of a hazard than humid summer days because cold air holds less moisture than warm air.) In the United Kingdom and Europe where high humidity is common, pilots must be constantly on the alert for carb icing and take corrective action **before** an irretrievable situation arises. If the engine fails due to carb icing, it may not re-start (even if it does, the delay could be critical).

b) Carb icing can occur in clear air and is therefore made more dangerous by the lack of any visual warning. In cloud, the icing risk may be higher but the pilot is less likely to be caught unawares.

c) Specific warnings of induction system icing are not normally included in aviation weather forecasts. Pilots must therefore use knowledge and experience. The closer the temperature and dewpoint readings, the greater the relative humidity. However, the humidity reported at an aerodrome may bear little relation to the humidity at flying altitudes. When dewpoint information is not available, assume high humidity particularly when:

- in cloud and fog; these are water droplets and the relative humidity should be assumed to be 100%;

- in clear air where cloud or fog may have just dispersed, or just below the top of a haze layer;
- just below cloud base or between cloud layers (highest liquid water content is at cloud tops);
- in precipitation, especially if persistent;
- the surface and low level visibility is poor, especially in early morning and late evening, and particularly near a large area of water; or
- the ground is wet (even with dew) and the wind is light.

However, the lack of such indications does not mean low humidity.

d) The chart shows the wide range of ambient conditions in which carb icing is most likely. Particular note should be taken of the much greater risk of serious icing with descent power.

5 RECOGNITION

a) Paragraphs 5, 6 and 7 are intended as a general guide to assist you to avoid icing, but reference must be made to the relevant sections of the Pilot's Operating Handbook or Flight Manual for specific procedures related to the particular airframe/ engine combinations. **These may vary for a different model of the same aircraft type**.

b) With a fixed pitch propeller, a slight drop in rpm and performance (airspeed and/or altitude) are the most likely indications of the onset of carb icing. This **loss of rpm** can be smooth and gradual and the usual reaction is to open the throttle slightly to compensate. However, this, whilst restoring power, hides the loss. As icing builds up, rough running, vibration, further loss of performance and ultimately engine stoppage may follow. The primary detection instrument is the **rpm gauge** in conjunction with ASI and altimeter.

c) With a constant speed propeller, and in a helicopter, the loss of power would have to be large before a reduction in rpm occurs. Onset of icing is even more insidious, but there will be a **drop in manifold pressure** and a performance reduction. In this case the primary detection instrument is the **manifold pressure gauge.**

d) In steady level flight, an exhaust gas temperature gauge, if fitted, may show a decrease in temperature before any significant decrease in engine and aircraft performance.

6 GENERAL PRACTICES

a) Some engines have electric heaters which on selection directly increase the temperature of the carburettor body, encouraging ice to clear. A similar effect may be obtained in a liquid-cooled engine by directing the flow of coolant.

b) On other air-cooled engines, carb icing is normally cleared by the pilot selecting an alternative air source which supplies air (heated in an exhaust heat exchanger), which melts the ice obstruction. This source by-passes the normal intake filter.

c) Fuel injected engines generally have an alternate air intake located within the engine cowling via a valve downstream from the normal air intake. Alternate air is warmed by engine heat, and does not normally pass through a heat exchanger.

d) Always use **full** heat whenever carb heat is applied; partial hot air should only be used if an intake temperature gauge is fitted and only then if specifically recommended in the Flight Manual or Pilot's Operating Handbook.

e) Select carburettor body heat whenever carb icing is likely. Hot air should be selected:

- as a matter of routine, at regular intervals to prevent ice build-up;
- whenever a drop in rpm or manifold pressure, or rough engine running, is experienced;
- when carb icing conditions are suspected; and
- when flying in conditions within the high probability ranges indicated in the chart.

But always be aware that hot air, while selected, reduces engine power, as, to a much lesser extent, does body heating. This may be critical in certain flight phases.

f) During the cruise, carburettor heat should be applied at regular intervals, to prevent carburettor ice forming. It should be selected for long enough (at the very least 15 seconds, but considerably more in certain aircraft) to pre-empt the loss of engine power or restore power to the original level.

g) If icing has caused a loss of power, and the hot air disperses it, re-selection of cold air should produce an increase in rpm or manifold pressure over the earlier reading. This is a useful check to see whether ice is forming, but does not prove that all the ice has melted! Carry out further checks until there is **no** resultant increase, monitor the engine instruments, and increase the frequencies of the routine checks, as it may re-occur. Absence of carb icing should produce no increase in rpm or manifold pressure beyond that noted prior to the use of hot air.

h) Remember, selection of hot air when ice is present may at first make the situation appear worse, due to an increase in rough running as the ice melts and passes through the engine. If this happens **the temptation to return to cold air must be resisted** so that the hot air has time to clear the ice. **This time may be in the region of 15 seconds**, which will, in the event, feel like a very long time!

i) Unless necessary, the continuous use of hot air at high power settings should be avoided. However, carburettor heat should be applied early enough **before** descent to warm the intake, and should remain fully applied during that descent, as the engine is more susceptible to carb icing at low power settings.

7 PILOT PROCEDURES

a) *Maintenance*

Periodically check the carb heating system and controls for proper condition and operation. Pay particular attention to seals which may have deteriorated, allowing the hot air to become diluted by cold air.

b) *Start Up*

Start up with the carb hot air control in the **COLD** position.

c) *Taxiing*

Although carb body heat should normally be selected ON, generally the use of carb hot air is not recommended while taxiing - the air is usually unfiltered when in the HOT position. However, ice may build up at the low taxiing power settings, and if not removed may cause engine failure after take-off. If carburettor heat is needed – USE IT.

d) *Ground Power Checks*

Select carburettor hot air fully ON for at least 15 seconds. Check that there is a **significant** power decrease when hot air is selected (typically 75–100 rpm or 3-5" of manifold pressure) and that power is regained (but to a level no higher than before) when cold air is re-selected. If the power returns to a higher value, ice was present and further checks should be carried out until the ice has cleared.

e) *Immediately Prior to Take-Off*

Since icing can occur when taxiing with low power settings, or when the engine is idling, select carb hot air ON for a minimum of 15 seconds and then OFF, immediately before take-off to clear any build-up. If the aircraft is kept waiting at the holding point in conditions of high humidity, it may be necessary to carry out the run-up drill more than once to clear ice which may have formed.

f) *Take-Off*

Ensure the engine is warm enough to provide carb body heat if appropriate. Take-off should **only** be commenced when you are sure the engine is developing full power. When at full power and as airspeed is building, you must check that the full throttle rpm and/or manifold pressure is as expected. **Carburettor hot air must NOT be used during take-off** unless specifically authorised in the Flight Manual or Pilot's Operating Handbook.

g) *Climb*

Be alert for symptoms of carb icing, especially when visible moisture is present or if conditions are in the high probability ranges in the chart. Be aware if your Flight Manual restricts the use of carb heat at full power.

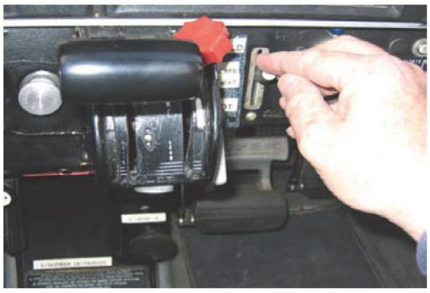
h) *Cruise*

Avoid clouds as much as possible. (Note that few piston-engined aircraft are cleared for flight in airframe icing conditions.) Monitor appropriate engine instruments for any changes which could indicate icing. If a body heat system is fitted, check it is ON whenever carb icing is possible. If a hot air system is fitted, make a carb heat check (see below) at least every 10 minutes (more frequently if conditions are conducive to icing).

Use full heat and note the warning of paragraph 6(h), it may take 15 seconds or more to clear the ice and the engine will continue to run roughly as the ice melts and passes through the engine. If the icing is so severe that the engine has died, keep the hot air selected as residual heat in the rapidly cooling exhaust may be effective (opening the throttle fully and closing the mixture control for a while may also help).

i) *Carburettor heat check*

- Note the RPM/Manifold Pressure (consider slightly increasing power beforehand to prevent a reduction in performance during the check).
- Apply full Carb heat for at least 15 seconds.
- Return Carb heat to Cold. The RPM/Manifold Pressure will return to approximately the earlier indication if there was no icing. If it is **higher** - icing was present, and may not yet be completely clear, so repeat the check until no increase results.



j) *Descent and Approach*

Carb icing is much more likely at reduced power, so select carb heat **before, rather than after**, power is reduced for the descent, and especially for a practice forced landing or a helicopter autorotation, i.e. before the exhaust starts to cool. (A full carb heat check just before selecting hot air for the descent is advisable.) Maintain FULL heat during long periods of flight with reduced power settings. At intervals of about 500 ft (or more frequently if conditions require), increase power to cruise setting to warm the engine and to provide sufficient heat to melt any ice.

k) *Downwind*

Ensure that the downwind check includes the cruise carburettor heat check at paragraph 6(i) above. If you select and leave the heat on, however, speed or altitude will reduce on the downwind leg unless you have added some power beforehand.

l) *Base Leg and Final Approach*

Unless otherwise stated in the Pilot's Operating Handbook or Flight Manual, the HOT position should be selected well before power is reduced and retained to touchdown. On some engine installations, to ensure better engine response and to permit a go-around to be initiated without delay, it may be recommended that the carb hot air be returned to COLD at about 200/300 ft on finals.

m) *Go-around or Touch and Go*

Ensure the carb hot air is COLD, ideally before, or simultaneously as, power is applied for a go-around.

n) *After Landing*

Return hot air to the COLD setting before taxiing, if not already set COLD.

8 SUMMARY

- Icing forms stealthily.
- Some aircraft/engine combinations are more susceptible than others.
- Icing may occur in warm humid conditions and is a possibility at any time of the year in the UK.
- MOGAS makes carb icing more likely.
- Low power settings, such as in a descent or in the circuit, are more likely to produce carb icing.
- Warming up the engine before take-off improves the effectiveness of any carb body heat.
- Use full carb hot air frequently when flying in conditions where carb icing is likely. Remember the RPM gauge is the primary indication for a fixed pitch propeller; manifold pressure for variable pitch.
- Treat the carb hot air as an ON/OFF control – either full hot or full cold.
- It takes time for the heat to work and the engine may run roughly while ice is clearing.
- Timely use of appropriate procedures can PREVENT THIS PROBLEM.

FINALLY

In the event of carb heat system failure in flight:

- Avoid likely carb icing conditions.
- Maintain high throttle settings – full throttle if possible.
- Weaken the mixture slightly.
- Land as soon as reasonably possible.

9.2. Instruction 1070AB Issued by Lycoming

LYCOMING
652 Oliver Street
Williamsport, PA. 17701 U.S.A.
Telephone +1 (800) 258-3279 U.S. and Canada (Toll Free)
Telephone +1 (570) 323-6181 (Direct)
Facsimile +1 (570) 327-7101
Email Technicalsupport@lycoming.com
www.lycoming.com

SERVICE INSTRUCTION

DATE: April 8, 2020

Service Instruction No. 1070AB
(Supersedes Service Instruction No. 1070AA)
Engineering Aspects are
FAA Approved

SUBJECT: Specified Fuels for Spark-Ignited Gasoline Aircraft Engine Models
MODELS AFFECTED: Lycoming engine models as detailed in Table 3
TIME OF COMPLIANCE: When refueling aircraft
REASON FOR REVISION: Added listings for IO-390-D to Table 3

NOTICE: Incomplete review of all the information in this document can cause errors. Read the entire Service Instruction to make sure you have a complete understanding of the requirements.

This Service Instruction identifies approved fuels for Lycoming spark-ignited gasoline aircraft engines. Fuels no longer known to be in production and distribution have been removed from this Service Instruction. For historical information, refer to the engine model Type Certificate Data Sheet or previous revisions of this Service Instruction.

⚠ **CAUTION:** AIRFRAME APPROVAL IS NECESSARY. THIS SERVICE INSTRUCTION IDENTIFIES APPROVED FUELS FOR ENGINES BASED ON THE ENGINE OPERATING LIMITATIONS INCLUSIVE OF OUTSIDE AIR TEMPERATURE, CYLINDER HEAD TEMPERATURE AND OIL TEMPERATURE.

AIRFRAME OPERATING LIMITATIONS CAN BE DIFFERENT THAN ENGINE OPERATING LIMITATIONS. REFER TO THE PILOT OPERATING HANDBOOK (POH), AIRFRAME TYPE CERTIFICATE (TC), AIRFRAME SUPPLEMENTAL TYPE CERTIFICATE (STC) OR OTHER APPLICABLE REGULATORY GUIDANCE FOR FUELS APPROVED AT THE AIRFRAME LEVEL.

Fuels approved for use in Lycoming engines in Table 3 include the following types:

- Aviation Fuels (Table 1)
- Automotive Fuels (Table 2)

⚠ **CAUTION:** ANY MIXTURE OF UNAPPROVED FUELS AND ADDITIVE MATERIALS THAT MAKES A LOWER THAN SPECIFIED OCTANE RATING, CAN CAUSE ENGINE DAMAGE. USE OF LOWER-THAN-SPECIFIED OCTANE FUEL COULD CAUSE DETONATION AND MECHANICAL DAMAGE TO THE ENGINE.

IF INCORRECT FUEL OR ADDITIVES ARE USED, REFER TO THE LATEST REVISION OF SERVICE BULLETIN NO. 398 FOR INSTRUCTIONS TO CORRECT THE FUEL CONTAMINATION.

General Aviation Manufacturers Association

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Fuel Specifications and Grades

Specifications that identify fuel types and grades approved for Lycoming engines are identified in Table 1: *Aviation Fuel Specifications and Fuel Grades* and Table 2: *Automotive Fuel Specifications and Fuel Grades*.

Engine Fuel Approvals

Table 3: *Fuels and Fuel Grades Approved for Use in Lycoming Engine Models* identify the approved fuel specifications and the associated fuel grade for each Lycoming engine model.

NOTICE: The fuel grades in Table 3 represent the Minimum Fuel Grade required for the engine specified and the associated Engine Operating Limitations. Higher fuel grades under the same specification can be used. For example, ASTM D7547 Grade UL 94 can be used in place of ASTM D7547 Grade UL 91.

Table 1
Aviation Fuel Specifications and Fuel Grades

	Fuel Specification	Fuel Grades	Color
LEADED	***DEF-STAN 91-090*** ***Standard Specification for Aviation Gasolines***	100LL	Blue
	ASTM D910: ***Standard Specification for Aviation Gasolines***	100 100LL 100VLL	Green Blue Blue
	TU 38.5901481-96: ***High-Octane Gasoline for Gasoline Engines*** Ukrainian National Standard	91	Yellow
	GOST 1012-72: ***Aviation petrol*** Russian National Standard	B91/115 B95/130	Green Amber
UNLEADED	***ASTM D7547:*** ***Standard Specification for Unleaded Aviation Gasolines***	UL 91 UL 94	Clear to Yellow (no dye)
	DEF-STAN 91-090 ***Standard Specification for Unleaded Aviation Gasolines***	UL 91	Clear to Yellow (no dye)
	HJELMCO Oil, INC.: HJELMCO 91/96 UL is the registered trade-name for colorless unleaded fuel made by HJELMCO Oil, Inc. of Sollentuna, Sweden	HJELMCO 91/96 UL	Clear to Yellow (no dye)

⚠ **CAUTION:** WHEN USING THE UNLEADED FUELS IDENTIFIED IN TABLE 1, LYCOMING OIL ADDITIVE P/N LW-16702, OR AN EQUIVALENT FINISHED PRODUCT SUCH AS AEROSHELL 15W-50, MUST BE USED.

NOTICE: Isopropyl alcohol in amounts not to exceed 1% by volume can be added only to **aviation fuel** (not automotive fuel) to prevent ice formation in fuel lines and tanks. Although approved for use in Lycoming engines, do not use isopropyl alcohol in the aircraft fuel systems unless approved by the aircraft manufacturer.

Table 2
Automotive Fuel Specifications and Fuel Grades

FUEL SPECIFICATION	FUEL GRADES
ASTM D4814-09b: ***Standard Specification for Automotive Spark-Ignition Engine Fuel*** Ordering Requirements: Vapor Pressure: Class A-4 Oxygenate Content: For blends containing one or more oxygenates, oxygenate content are not to exceed 1.0 volume percent.	91 AKI 93 AKI
EN 228:2014: ***Automotive fuels - Unleaded petrol - Requirements and test methods*** Ordering Requirements: Vapor Pressure: Class A Oxygenate Content: For blends containing one or more oxygenates, oxygenate content are not to exceed 1.0 volume percent.	Super Plus (Minimum 88 MON and 98 RON)

⚠ **CAUTION:** IN COMPLIANCE WITH THIS SERVICE INSTRUCTION, THE AUTOMOTIVE FUEL MUST AGREE WITH ALL SPECIFICATIONS IN TABLE 2. AUTOMOTIVE GASOLINE THAT IS NOT IN CONFORMANCE WITH THE SPECIFICATIONS IN TABLE 2 IS NOT TO BE USED.

WHEN USING THE AUTOMOTIVE FUELS IDENTIFIED IN TABLE 2, LYCOMING OIL ADDITIVE P/N LW-16702, OR AN EQUIVALENT FINISHED PRODUCT SUCH AS AEROSHELL 15W-50, MUST BE USED.

NOTICE: Refer to the latest revision of Service Instruction No. 1534 for information on service recommendations for long-term storage of engines that use automotive fuel.

The automotive fuels in Table 2 must be in conformance with ASTM D4814-09b or EN 228:2014. In these specifications, the automotive fuel is identified by an Anti-Knock Index (AKI) or in the case of EN 228 as "Super Plus," a grade designation. The AKI is an octane rating and is the arithmetic average of the Research Octane Number (RON) and Motor Octane Number (MON).

$$(RON + MON)/2 = AKI$$

Automotive fuels usually have Reid Vapor Pressure (RVP) values between 7 and 9.3 psi (48 and 64 kPa) in summer seasons but specifications for the RVP can be as high as 15 psi (103 kPa) in the winter. In some geographic regions, there is no upper limit to RVP in the winter season. As vapor pressure increases, the tendency for vapor lock will increase as well as fuel "boil off" at altitude. It is also possible that highly oxygenated fuels are not compatible with some fuel system components. In cases of material incompatibility, deterioration of metallic and non-metallic components can occur.

Automotive ground transportation fuels available direct to consumers (e.g. "pump gas") usually do not have labels with sufficient information to identify compliance with the requirements in Table 2. While indicated octane is generally necessary for display at retail points of sale, octane rating methods, fuel vapor pressure and oxygenate content can vary widely and are generally known only at the wholesale terminal.

Table 3
Fuels and Fuel Grades Approved for Use in Lycoming Engine Models

Engine Models	Leaded Aviation Fuels (Table 1)					Unleaded Aviation Fuels (Table 1)			Automotive Fuels (Table 2)		
	DEF-STAN 91-090	ASTM D910	TU 38	GOST 1012		ASTM D7547	DEF-STAN 91-090	HJELMCO	ASTM D4814		EN228
	100LL	100* 100LL 100VLL	91*	B91/115*	B95/130*	UL 91 UL 94	UL 91	91/96	91 AKI	93 AKI	Super Plus
O-235											
-C, -E, -H	●	●	●	●	●	●	●	●		●	●
-F, -G, -J	●	●			●						
-K, -L, -N	●	●			●	●	●			●	●
-M, -P	●	●				●	●			●	●
O-290											
-D	●	●	●	●	●	●	●	●		●	●
O-320											
-A, -B, -C, -D, -E	●	●	●	●	●	●	●	●		●	●
-H	●	●									
IO-320											
-A, -B, -D, -E	●	●	●	●	●	●	●	●		●	●
-C, -F	●	●			●						
AIO-320											
-A, -B, -C	●	●	●	●	●	●	●	●		●	●
LIO-320											
-B	●	●	●	●	●	●	●	●		●	●
-C	●	●			●						
AEIO-320											
-D, -E	●	●	●	●	●	●	●	●		●	●
O-360											
-A, -B, -C, -D, -F, -G, -J	●	●	●	●	●	●	●	●		●	●
-E	●	●									
HO-360											
-A, -B	●	●	●	●	●	●	●	●		●	●
-C	●	●	●	●	●	●	●			●	●

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Table 3 (Cont.)
Fuels and Fuel Grades Approved for Use in Lycoming Engine Models

Engine Models	Leaded Aviation Fuels (Table 1)					Unleaded Aviation Fuels (Table 1)			Automotive Fuels (Table 2)		
	DEF-STAN 91-090	ASTM D910	TU 38	GOST 1012		ASTM D7547	DEF-STAN 91-090	HJELMCO	ASTM D4814		EN228
	100LL	100* 100LL 100VLL	91*	B91/115*	B95/130*	UL 91 UL 94	UL 91	91/96	91 AKI	93 AKI	Super Plus
IO-360											
-A, -C, -D, -F	●	●			●						
-J, -K	●	●									
-B, -E, -L, -M, -N, -P	●	●	●	●	●	●	●	●		●	●
LO-360											
-A	●	●	●	●	●	●	●	●		●	●
-E	●	●									
TO-360											
-A, -C, -E, -F	●	●									
VO-360											
-A, -B	●	●	●	●	●			●			
AIO-360											
-A, -B	●	●			●						
HIO-360											
-A, -C, -D, -E, -F	●	●			●						
-B	●	●	●	●	●	●	●	●		●	●
-G	●	●	●	●	●	●	●			●	●
IVO-360											
-A	●	●	●	●	●	●	●	●		●	●
LIO-360											
-B, -M	●	●	●	●	●	●	●	●		●	●
-C	●	●			●						
LTO-360											
-A, -E	●	●									

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Table 3 (Cont.)
Fuels and Fuel Grades Approved for Use in Lycoming Engine Models

Engine Models	Leaded Aviation Fuels (Table 1)					Unleaded Aviation Fuels (Table 1)			Automotive Fuels (Table 2)		
	DEF-STAN 91-090	ASTM D910	TU 38	GOST 1012		ASTM D7547	DEF-STAN 91-090	HJELMCO	ASTM D4814		EN228
	100LL	100* 100LL 100VLL	91*	B91/115*	B95/130*	UL 91 UL 94	UL 91	91/96	91 AKI	93 AKI	Super Plus
TIO-360											
-A, -C	●	●									
AEIO-360											
-A	●	●			●						
-B, -H	●	●	●	●	●	●	●	●		●	●
LHIO-360											
-C, -F	●	●									
IO-390											
-A, -C, -D	●	●			●						
HIO-390											
-A	●	●									
AEIO-390											
-A	●	●									
O-435											
-A, -C (except -A2)	●	●	●	●	●	●	●	●			
-A2	●	●									
GO-435											
-C, -C2 (See note below for -C2)	●	●	●	●	●	●	●	●			
NOTE: GO-435-C2 engine models equipped with carburetor setting 10-3391 must use 91/96 HJELMCO grade or better fuel. Engines equipped with carburetor settings 10-3391-1 or PS-5BD can use fuels specified for GO-435-C model engines.											
VO-435											
-A, -6, -23	●	●	●	●	●			●			
-B	●	●			●						

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Table 3 (Cont.)
Fuels and Fuel Grades Approved for Use in Lycoming Engine Models

Engine Models	Leaded Aviation Fuels (Table 1)					Unleaded Aviation Fuels (Table 1)			Automotive Fuels (Table 2)		
	DEF-STAN 91-090	ASTM D910	TU 38	GOST 1012		ASTM D7547	DEF-STAN 91-090	HJELMCO	ASTM D4814		EN228
	100LL	100* 100LL 100VLL	91*	B91/115*	B95/130*	UL 91 UL 94	UL 91	91/96	91 AKI	93 AKI	Super Plus
TVO-435											
-A, -B, -C, -D, -E, -F, -G, -25	●	●									
O-480											
-1, -3	●	●									
-A	●	●	●	●	●			●			
GO-480											
-B, -D, -F	●	●	●	●	●	●	●	●			
-C, -G	●	●			●						
GSO-480											
-A, -B	●	●									
IGO-480											
-A	●	●			●						
IGSO-480											
-A	●	●									
O-540											
-A, -B, -D, -E, -F, -G, -H, -J	●	●	●	●	●	●	●	●		●	●
-L	●	●									
-9, -9A	●	●									
IO-540											
-A, -B, -E, - G, -J, -K, -L, -M, -P, -R, -S, -U, -AA, -AC, -AE	●	●			●						
-C, -D, -N, -T, -V	●	●	●	●	●	●	●	●		●	●
-W, -AB, -AF	●	●				●	●			●	●

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Table 3 (Cont.)
Fuels and Fuel Grades Approved for Use in Lycoming Engine Models

Engine Models	Leaded Aviation Fuels (Table 1)					Unleaded Aviation Fuels (Table 1)			Automotive Fuels (Table 2)		
	DEF-STAN 91-090	ASTM D910	TU 38	GOST 1012		ASTM D7547	DEF-STAN 91-090	HJELMCO	ASTM D4814		EN228
	100LL	100* 100LL 100VLL	91*	B91/115*	B95/130*	UL 91 UL 94	UL 91	91/96	91 AKI	93 AKI	Super Plus
VO-540											
-A, -B	●	●	●	●	●	●	●	●			
-C	●	●			●						
HIO-540											
-A	●	●			●						
IGO-540											
-A, -B	●	●			●						
IVO-540											
-A	●	●			●						
TEO-540											
-A, -C	●	●									
TIO-540											
-A, -C, -E, -F, -G, -H, -J, -K, -N, -R, -S, -T, -U, -V, -W, -AA, -AB, -AE, -AF, -AG, -AH, -AJ, -AK	●	●									
TVO/TIVO-540											
-A	●	●									
AEIO-540											
-D	●	●	●	●	●	●	●	●		●	●
-L	●	●									
IGSO-540											
-A, -B	●	●									
LTIO-540											
-F, -J, -K, -N, -R, -U, -V, -W	●	●									

Table 3 (Cont.)
Fuels and Fuel Grades Approved for Use in Lycoming Engine Models

Engine Models	Leaded Aviation Fuels (Table 1)					Unleaded Aviation Fuels (Table 1)			Automotive Fuels (Table 2)		
	DEF-STAN 91-090	ASTM D910	TU 38	GOST 1012		ASTM D7547	DEF-STAN 91-090	HJELMCO	ASTM D4814		EN228
	100LL	100* 100LL 100VLL	91*	B91/115*	B95/130*	UL 91 UL 94	UL 91	91/96	91 AKI	93 AKI	Super Plus
TIO-541											
-A, -E	●	●									
TIGO-541											
-D, -E, -G	●	●									
IO-580											
-A, -B	●	●			●						
AEIO-580											
-B	●	●			●						
IO-720											
-A, -B, -C, -D	●	●			●						

* - Continuous use of high lead fuels can cause increased lead deposits both in combustion chambers and spark plugs causing roughness in engine operation and scored cylinder walls. It is recommended that the use of this fuel be limited wherever possible. However, when high lead fuel is used, do periodic inspections of combustion chambers, valves, and valve ports more frequently and rotate or clean spark plugs whenever lead fouling is found. See the latest revision of Service Letter No. L192.